Weed Technology. 1998. Volume 12:522–526

The Influence of Weed Management in Wheat (*Triticum aestivum*) Stubble on Weed Control in Corn (*Zea mays*)[1]

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Abstract: The objectives of this study were to determine how the timing of weed management treatments in winter wheat stubble affects weed control the following season and to determine if spring herbicide rates in corn can be reduced with appropriately timed stubble management practices. Field studies were conducted at two sites in Ohio between 1993 and 1995. Wheat stubble treatments consisted of glyphosate (0.84 kg ae/ha) plus 2,4-D (0.48 kg ae/ha) applied in July, August, or September, or at all three timings, and a nontreated control. In the following season, spring herbicide treatments consisted of a full rate of atrazine (1.7 kg ai/ha) plus alachlor (2.8 kg ai/ha) preemergence, a half rate of these herbicides, or no spring herbicide treatment. Across all locations, a postharvest treatment of glyphosate plus 2,4-D followed by alachlor plus atrazine at half or full rates in the spring controlled all broadleaf weeds, except giant ragweed, at least 88%. Giant foxtail control at three locations was at least 83% when a postharvest glyphosate plus 2,4-D treatment was followed by spring applications of alachlor plus atrazine at half or full rates. Weed control in treatments without alachlor plus atrazine was variable, although broadleaf control from July and August glyphosate plus 2,4-D applications was greater than from September applications. Where alachlor and atrazine were not applied, August was generally the best timing of herbicide applications to wheat stubble for reducing weed populations the following season.

Nomenclature: Giant ragweed, *Ambrosia trifida* L. #[3] AMBTR; giant foxtail, *Setaria faberi* Herrm. # SETFA; alachlor, 2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide; atrazine, 6-chloro-*N*-ethyl-*N′*-(1-methylethyl)-1,3,5-triazine-2,4-diamine; glyphosate, *N*-(phosphonomethyl)glycine; 2,4-D, (2,4-dichlorphenoxy)acetic acid; corn, *Zea mays* L.; winter wheat, *Triticum aestivum* L.
Additional index words: Ecofallow, fall application, glyphosate, 2,4-D, wheat stubble management, AMBEL, AMBTR, CHEAL, CIRAR, CYPES, DIGSA, ERICA, PANDI, POLPY, SETFA.
Abbreviations: DAP, days after planting; PRE, preemergence.

INTRODUCTION

In Ohio and surrounding states, soft red winter wheat is typically harvested in July, after which many fields remain fallow until the next spring. Although the growing season is often too short for a second crop, many weed species can complete their life cycles following wheat harvest and disperse seeds in these fields. For example, barnyardgrass (*Echinochloa crus-galli* (L.) Beauv. # ECHCG) can flower within 25 d after wheat harvest and produce seeds within 45 d (Ramsel and Wicks 1988; Vander Vorst et al. 1983). Therefore, seed rain from weeds present after wheat harvest could be an important source of weed infestations in crops such as no-till corn planted the following spring.

Wheat stubble weed management is more common in the central Great Plains of the United States where corn or sorghum [*Sorghum bicolor* (L.) Moench] is planted no-till into wheat stubble following a 10-mo fallow (Vander Vorst et al. 1983). Wicks (1986) found that herbicide applications within 35 d after wheat harvest reduced barnyardgrass seed production 75% compared with barnyardgrass treated at 50 d after wheat harvest. Where atrazine plus glyphosate was applied 25, 45, and 60 d after wheat harvest, barnyardgrass produced 79, 600, and 1,020 panicles/30 m^2, respectively, at the end of the season (Vander Vorst et al. 1983). However, all of these studies included a fall application of atrazine, a treatment not registered for use in Ohio.

[1] Received for publication September 15, 1997, and in revised form May 11, 1998. Salaries and research support provided by state and federal funds appropriated to the Ohio Agricultural Research and Development Center, The Ohio State University. Manuscript 142-97.

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[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

Table 1. Weed heights at the July, August, and September post-wheat-harvest application timings in 1993, 1994, and 1995.

Weed species[a]	1993			1994			1995		
	July	Aug.	Sept.	July	Aug.	Sept.	July	Aug.	Sept.
	cm								
CIRAR	—[b]	—	—	13–25	25–64	25–91	—	—	—
CHEAL	—	—	—	5–25	25–76	25–76	5–20	25–61	25–76
AMBEL	15–51	30–61	51–91	—	—	—	—	—	—
PANDI	15–61	30–51	30–76	—	—	—	15–30	30–61	30–71
SETFA	15–46	30–71	51–91	8–20	30–76	30–76	15–25	30–61	30–76
AMBTR	—	—	—	13–51	30–91	61–102	—	—	—
ERICA	15–61	61–91	51–91	—	—	—	15–61	51–91	61–91
POLPY	20–30	30–51	35–76	5–20	20–30	20–30	—	—	—

[a] CIRAR, Canada thistle at Wooster in 1994; CHEAL, common lambsquarters at Lockbourne in 1993 and 1994 and Wooster in 1995; AMBEL, common ragweed at Wooster and Lockbourne in 1993; PANDI, fall panicum at Wooster in 1995; SETFA, giant foxtail at Wooster in 1993–1995 and Lockbourne in 1993; AMBTR, giant ragweed at Wooster in 1994; ERICA, horseweed at Wooster in 1993 and 1995; POLPY, Pennsylvania smartweed at Lockbourne in 1993.

[b] Weed species not present.

Many Ohio farmers manage weeds following the winter wheat harvest with nonselective herbicides, mowing, or a combination of mowing followed by herbicides. In many fields, weeds in wheat stubble are left unmanaged. Postharvest tillage is not considered an option for suppressing these weeds in areas where no-till practices are used to minimize soil erosion. The influence of wheat stubble weed management on weed populations the following season has not been studied in Ohio.

Economic considerations have led to research on timely applications of herbicides at reduced rates for weed management. Loux et al. (1998) found that single and sequential applications of herbicides at reduced rates were as effective in controlling weeds as were herbicides applied at the registered rates in grower's fields where the density was not severe. One way to reduce weed density, and potentially improve weed control in corn, is to limit production of seeds the previous season (Hoefer et al. 1981). Restriction of weed seed production by stubble management may increase the effectiveness of subsequent reduced-rate-herbicide weed management programs. Therefore, the objectives of this study were to determine the influence of the timing of nonselective herbicide treatments in wheat stubble on weed control the following season and to determine if rates of herbicides applied to corn in the spring can be reduced with appropriately timed wheat stubble management practices.

MATERIALS AND METHODS

Field experiments were established in soft red winter wheat stubble fields in Lockbourne, OH, in 1993 and 1994 and Wooster, OH, in 1993, 1994, and 1995. The soil type at Lockbourne was a Crosby silt loam (Mesic Aeric Ochraqualf) with pH 5.6 and 2.9% organic matter. The soil type in Wooster was a Wooster silt loam (Typic Fragiudalf) with 2.9% organic matter and pH 6.2. Plots were 3 by 9 m and were arranged in a randomized complete block design with four replications. The treatments were a factorial set consisting of five post-wheat-harvest treatments (in wheat stubble) and three corn preemergence (PRE) management practices the following spring.

Winter wheat was machine harvested and the straw removed in the first week of July at all locations. The post-wheat-harvest herbicide treatments consisted of 0.84 kg/ha glyphosate plus 0.48 kg/ha 2,4-D applied to wheat stubble in either July, August, or September, or at all three timings, and a nontreated control. All herbicide treatments that included glyphosate were applied in a spray volume of 93 L/ha at 220 kPa with flat fan nozzle tips[4] and included 0.5% (v/v) nonionic surfactant[5] and 0.02 kg/L ammonium sulfate. Application dates and weed sizes are shown for each location in Table 1.

In spring, all plots received an application of glyphosate plus 2,4-D at the rates listed above, after which corn was planted no-till. At Wooster, 'Dekalb 524' field corn was planted during the first week in May of each year at a rate of 78,800 seeds/ha. 'Pioneer Brand 3346' field corn was planted at Lockbourne at a similar rate during the last week of April in 1994 and 1995.

The three corn PRE herbicide treatments consisted of a full rate of atrazine (1.7 kg/ha) plus alachlor (2.8 kg/ha) applied within 2 d after planting (DAP), a half rate of that herbicide mixture, and a nontreated control. Corn herbicide treatments were applied in a spray volume of 186 L/ha at 220 kPa with flat fan nozzle tips.[4]

Weed control in corn was rated at all locations about 60

[4] Nozzle tips numbered 8001 for applications including glyphosate and 8002 for corn herbicide treatments. Spraying Systems Co., Wheaton, IL 60188.

[5] X-77, a mixture of alkaryl polyoxyethylene glycols, free fatty acids, and isopropanol. Valent USA Corp., P.O. Box 8025, Walnut Creek, CA 94596-8025.

Table 2. The effect of postharvest wheat stubble application timing on weed control in no-till corn (60 DAP) without a spring preemergence herbicide application. Values in the table represent weed control averaged across locations and years.

Time of wheat stubble application[a]	AMBEL	CHEAL	CIRAR	SETFA
	%			
July	91 a[b]	94 a	81 ab	74 a
August	88 a	95 a	94 a	71 a
September	0 b	69 b	75 b	55 b
July plus August plus September	87 a	88 a	92 a	71 a
Nontreated control	0 b	0 c	0 c	0 c

[a] Glyphosate at 0.84 kg/ha plus 2,4-D at 0.48 kg/ha.

[b] Numbers followed by the same letter within columns are not significantly different. Letters were assigned to transformed means using the transformed Fisher's protected LSD at an alpha level of 0.05.

Table 3. Monthly rainfall April to September in 1993–1996 at Wooster, OH.

Month	1993	1994	1995	1996
	cm			
April	9.8	11.3	7.9	12.4
May	3.7	4.7	11.5	11.4
June	10.7	10.9	7.7	12.7
July	5.7	5.3	9.1	9.4
August	1.5	12.7	8.3	4.6
September	10.1	3.1	2.7	12.9

DAP using a scale from 0 (no control) to 100% (death of all plants). Weed fresh weight biomass was sampled in Wooster plots between corn rows using four 0.5-m^2 quadrats per plot prior to corn harvest. Corn yields were determined by hand-harvesting the two center rows of each plot when corn was at physiological maturity and samples were adjusted to 15.5% moisture prior to analysis. Corn was not harvested at Lockbourne. Visual ratings were arcsine transformed before analysis of variance. Fisher's protected LSD test at an alpha level of 0.05 was used to separate transformed means. The means are presented in original form for clarity. There were no significant treatment by location interactions for weed control, so data are presented across locations. There were significant treatment by location interactions for corn yield and weed biomass; therefore, data are presented by year.

RESULTS AND DISCUSSION

Weed Control in Corn Without Spring Treatments. Applications of glyphosate plus 2,4-D to wheat stubble in July, August, or July plus August plus September were more effective against weeds in the subsequent year's corn than was a single herbicide application in September (Table 2). Springtime (60 DAP) common ragweed (*Ambrosia artemisiifolia* L. # AMBEL) density was not affected by September glyphosate plus 2,4-D application (0% control), probably because of low susceptibility of common ragweed at relatively advanced maturity (51 to 91 cm height). Therefore, seed production may have been completed before the herbicide treatment was applied in September.

Canada thistle [*Cirsium arvense* (L.) Scop. # CIRAR] control was 94% from August applications of glyphosate plus 2,4-D, which was significantly better control than that from the September application (75% control) (Table 2). Canada thistle is a perennial plant that reproduces by seeds and creeping roots. Greater than 12 cm of rain fell in August 1994, which may have promoted both Canada thistle growth and translocation of glyphosate to the perennating creeping roots (Table 3).

Common lambsquarters (*Chenopodium album* L. # CHEAL) and giant foxtail were controlled 69 and 55%, respectively, from the September application. This relatively low percent control was probably due to the advanced growth stage of these weeds, since seed production was nearing completion in mid-September. Therefore, the herbicide may have had only a limited effect on plant growth and reproduction. Larger weeds may have intercepted a large proportion of the herbicide and thus protected the smaller plants from the control measures, allowing them to produce seeds. Wicks et al. (1989) surveyed the success of weed management in 146 wheat stubble fields and found only 55% of those sprayed after wheat harvest had excellent (90 to 100%) weed control because weeds were generally too large at the time of application.

Weed Control in Corn with Spring Treatments. None of the applications of glyphosate plus 2,4-D to wheat stubble influenced annual weed control the following season when a spring treatment of atrazine plus alachlor was applied. Therefore, data in Table 4 are presented as averages across fall treatments. The full and half rates of atrazine plus alachlor had better weed control than the non-spring-treated plots (Table 4). There were significant interactions due to the resulting high weed densities in the nontreated control and the September application with no spring application of atrazine plus alachlor treatments. The full rate of atrazine plus alachlor controlled all weeds at least 85%, with the exception of fall panicum (*Panicum dichotomiflorum* Michx. # PANDI) (76%). Control of all weed species was similar from the half and full rates of atrazine plus alachlor with the exception of giant ragweed. The half rate controlled 67% of the giant ragweed, but 99% of common ragweed, common lambsquarters, Pennsylvania smartweed (*Polygonum pensylvanicum* L. # POLPY), and horseweed

Table 4. The influence of preemergence atrazine plus alachlor on weed control in no-till corn. Data were averaged across all postharvest wheat stubble treatments. Values in the table represent weed control averaged across locations and years.

Rate of spring treatment[a]	AMBEL	AMBTR	CHEAL	ERICA	PANDI	POLPY	SETFA
	%						
0	66 b[b]	41 c	86 b	56 b	50 b	64 b	67 b
Half	99 a	67 b	99 a	99 a	68 a	100 a	83 a
Full	99 a	85 a	98 a	99 a	76 a	100 a	89 a

[a] The full-rate treatment applied was 1.7 kg/ha atrazine plus 2.8 kg/ha alachlor PRE.

[b] Numbers followed by the same letter within columns are not significantly different. Letters were assigned to transformed means using the transformed Fisher's protected LSD at an alpha level of 0.05.

[*Conyza canadensis* (L.) Cronq. # ERICA]. Fall panicum and giant foxtail control from the half rate was 68 and 83%, respectively, but these were not significantly different from weed control at the full rate.

Corn Yield and Weed Biomass. In plots that did not receive a PRE corn herbicide application, there were differences among wheat stubble treatments in corn yields among years; therefore, data for years are presented separately (Table 5). In 1994, the highest corn yields were obtained from plots treated with July, August, and the July plus August plus September applications. All of these treatments yielded better than the nontreated control and the September application. Weed biomass in 1994 did not reflect the large differences in corn yield (Table 5). Corn yield from the nontreated control in 1995 was lower than all other treatments with the exception of the September application. The nontreated control also had the most weed biomass, but only August and the multiple application treatment (July plus August plus September) had lower weed biomass. All postharvest wheat stubble management treatments had higher corn yields than the nontreated control in 1996. This trend was also present in weed biomass, where all treatments with the exception of the September application had less weed biomass than the nontreated control. The trend observed in weed biomass in each year was that the September application of glyphosate plus 2,4-D resulted in higher amounts of weed biomass than the other application dates. This was probably due to the completed reproductive cycle of the weeds at the time of herbicide applications.

The corn yields at the half and full rates of atrazine plus alachlor application averaged across all post-wheat-harvest applications were not different from one another but were greater than the treatments without a spring application (data not shown). These results are similar to those of Teasdale (1995), who found no difference in corn yields between 25% and 100% rates of atrazine plus metolachlor PRE in three out of four seasons tested. The relationship between corn yield and weed biomass is expressed as an inverse linear function ($r^2 = 0.73$) (Figure 1). The data for this figure represent the average weed biomass and corn yield from 10 treatments over 3 yr. The full-rate spring treatments had greater corn yields and lower weed biomass compared with the nontreated control.

Our study was repeated across five year–locations, but each site was used for only one cycle of the experiment. When a corn herbicide treatment was not included, a July or August application of glyphosate plus 2,4-D to wheat stubble resulted in lower weed density in the subsequent season relative to the nontreated control. Differ-

Table 5. The effect of postharvest wheat stubble application timing on no-till corn yield and weed biomass without a spring preemergence herbicide at Wooster.

Wheat stubble treatments[a]	1994		1995		1996	
	Corn	Weed biomass[b]	Corn	Weed biomass	Corn	Weed biomass
	kg/ha					
Nontreated control	4,080	2,340	3,540	4,870	3,740	6,230
July	10,440	1,570	5,940	3,490	8,730	2,590
August	10,680	1,590	6,060	2,810	8,460	2,500
September	3,540	1,740	5,460	4,250	8,210	5,070
July plus August plus September	11,280	1,720	5,900	2,560	9,470	2,220
LSD (0.05)	2,520	680	2,200	1,450	2,160	2,520

[a] Glyphosate at 0.84 kg/ha plus 2,4-D at 0.48 kg/ha.

[b] Fresh weights of weeds.

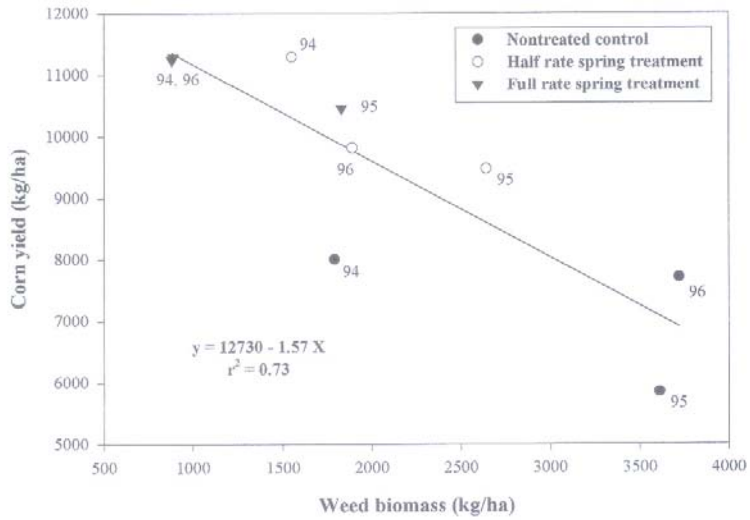

Figure 1. The relationship between corn yield and weed biomass from no-till corn preemergence herbicide treatments at Wooster. Data were averaged across wheat stubble management treatments; numbers indicate the year of the study.

ences in weed densities could not be detected in corn when wheat stubble applications were made in the summer prior to a half or full rate of the corn herbicides (atrazine plus alachlor) in the spring. However, we were unable to observe the possible multiple-season treatment effects of late summer glyphosate plus 2,4-D and reduced or full rates of atrazine plus alachlor that may have occurred over time. Future research should be directed toward investigating multiple-year effects of wheat stubble treatments on weed density the following season, as well as the interaction between wheat stubble treatments and reduced-rate spring treatments.

ACKNOWLEDGMENTS

The authors thank Tim Koch, Brian Sugerman, and Paul McMillen for assistance in data collection and in establishing, maintaining, and harvesting plots. The assistance of Dr. Paul Sprankie and partial funding from Monsanto Ag. Company are gratefully acknowledged.

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